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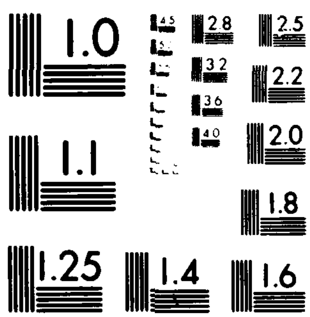

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Implementation of Mil Prime in the USAF

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IMPLEMENTATION OF MIL-PRIME IN THE USAF
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Abstract

Mil-Prime is a relatively new Air Force concept for writing contract specifications. Its intent is to emphasize the writing of requirements and their verification in functional terms related as closely as possible to a system's mission. The implementation of Mil-Prime was studied on the C-X landing gear and compared to the old procedures used on the C-5 landing gear. The AFIT thesis upon which this paper is based concluded that there are some inherent advantages in using Mil-Prime. It also concluded that several areas will continue to require close scrutiny and development if Mil-Prime is to be effective. Mil-Prime was seen to result in a more flexible and simple specification, but the process was seen as front-end loaded and more complex. The clarity of understanding between government and contractor was seen as the major advantage of Mil-Prime.

Introduction

In the years since World War II, the sophistication and cost of new weapon systems have steadily increased. The relatively inexpensive machine guns and gravity bombs of the World War II era have largely been replaced by infrared, electro-optical, and laser guided munitions, which in many cases cost over $1 million a copy. In this same period, the American people have demanded a better accounting of their tax dollars to ensure that these dollars are spent as effectively and efficiently as possible.

It is increasingly important for the Air Force to buy weapon systems that are cost effective. The Air Force must continue to cut costs while maintaining a high degree of technical sophistication and reliability. The Aeronautical Systems Division (ASD), Wright-Patterson AFB OH, which buys Air Force aeronautical weapon systems and subsystems, is a leader in cutting costs. Lt Gen Lawrence A. Skantze, ASD Commander, states:

> We are at the forefront of the Air Force's effort to mold new and existing technologies into superior weapon systems for our operational forces. We must meet this challenge in our era of tremendous budget pressures, where inflation and shrinking real dollar value limit us to fewer systems and smaller quantities . . . Our goal is to produce both mission effective and cost effective aeronautical systems.[1]

The costs of major weapon systems are driven, in part, by the following factors: attempts to deploy systems with new technology and high performance; low rates of production due to budget constraints and desires to maintain active production bases as long as possible; absence of price competition between contractors; lack of real motivation on the part of contractors to reduce costs; the impact of socio-economic programs, Government controls, and red tape; and a nationwide problem of reduced research and development expenditures and lessening of productivity.[2]

One particularly stubborn factor driving up costs is the barrier to innovation and creativity generated by over-constraining specifications incorporated into contracts.

The specifications, along with the work statement, drawings, and item description, formulate the heart of any request for proposal (RFP) and subsequent contract. Whether or not a contract will be successfully performed is quite often determined not at the time the contract is negotiated or the award made, but rather at the earlier time at which the purchase or performance description is written.[3] This paper describes both the traditional (over-constrained) process used by the U.S. Air Force and a new specification-writing process entitled "Mil-Prime."

There are approximately 45,500 military specifications and standards in the Department of Defense (DoD) library, each of which specifies numerous requirements with which defense contractors must comply. Of the 45,500 traditional specifications and standards, approximately 40,000 were written primarily for reprocurement purposes, and only approximately 500 specifications are considered to be key documents to be used in the acquisition of aeronautical weapon systems. These 500 documents, which, in turn, reference other documents, are very important because ASD has been using these specifications as the basis for its technical requirements, spending over $1.3 billion in research and development funds and approximately $4.8 billion in production funds each year to buy aeronautical systems and subsystems.[4]

The 45,500 traditional specifications and standards are generalized documents, i.e. they are not specifications for

specific weapon systems, and they fall into three categories: reprocurement, development, and general design. The reprocurement category is by far the largest in terms of numbers of documents. The development category includes the system specifications and subsystem specifications. The development category also includes the MIL-STD-490 Part I and Part II configuration item specifications for specific weapon systems, but this latter set of specifications is in addition to and separate from the 45,500 traditional specifications. The general design category includes those standards, e.g. reliability, maintainability, and quality assurance, sections of which are lifted out of and incorporated by reference into development specifications. The focus of this paper is on development specifications.

Definitions

1. Development specifications: the documents used by the research, development, and acquisition community within the DoD to specify how new products are to function and/or be built.

> Development specifications state the requirements for the design or engineering development of a product during the development period. Each development specification shall be in sufficient detail to describe effectively the performance characteristics that each configuration item is to achieve when a developed item is to evolve into a detail design for production.[5]

2. Reprocurement: the process of contracting for items which have already been developed by requiring compliance with "build-to" specifications (see Type II specifications below).

3. Subsystem Requirements Document: a document prepared by the Government, and incorporated into the request for proposal, which establishes the performance requirements for an aircraft's subsystems. The selected contractor will later transform this document into an air vehicle specification.[6]

4. Technical Requirement: the smallest unit of definition in a specification. The link in contract specifications between high order conceptual program goals and specific design detail.[7]

5. Type I (Part I) specification: a development specification which states the complete performance requirements of the product for the intended use; also called a "functional specification," a "design-to specification," and a "performance specification."[8]

6. Type II (Part II) specification: a specification which describes, in detail, the complete requirements for an item, including the materials to be used, their sizes and shapes, and how the item is to be fabricated and built. It provides a completely defined item, capable of manufacture by a competent manufacturer in the industry;[9] also called a "build-to specification."

Background

ASD is trying a new approach to the development of aeronautical specifications. According to Mr. Weingarten (ASD/EN), the gradual development of the 45,500 generalized specifications currently in the DoD system has caused numerous implementation problems. Some of the problems, as reported by users of these specifications, involve facets of design flexibility as follows:[10]

1. One specification often requires by reference the incorporation of other specifications. Referencing to a limited extent is certainly more desirable than repeating verbatim the words from another specification, but this tiering of specifications has in many cases become excessive. For example, one specification requires in its second tier the incorporation by reference of 3,111 other specifications.

2. The specifications are difficult to tailor to specific weapon systems being acquired. The Government engineer tends to require the potential contractors to accept a specification in its entirety, even if the mission that the aircraft is to support does not require the incorporation of the complete specification.

3. The specifications inhibit innovation. The specifications are conceived to be cast in concrete, even if the concepts incorporated in them have to be superseded by new technology.

4. The requirements in the specifications are often not practically verifiable. Two examples of this problem are as follows: (a) MIL-B-8584 requires that an aircraft parking brake hold an aircraft on an 18° slope, but there is not any verification section for this requirements, which means that a contractor would not be obligated to test his design to see if it meets this requir[illegible] (b) MIL-A-8865 limits the pounds per [illegible]nch of allowable pressure on the [illegible] a fuselage that is ditched in the w[illegible], but there is not any corresponding verification section, and furthermore, there is not any requirement for the aircraft to remain afloat long enough for the crew and passengers to evacuate once the aircraft is in the water.

5. Specifications are sometimes gold-plated. Less expensive methods to build a part with the same function are prohibited by rigid adherence to the specifications. Gold-plating can also refer to a requirement that is impossible to meet. For example, MIL-L-38207 requires that the material covering the clock mainspring in an aircraft cockpit be made of an "unbreakable" alloy.

6. Specifications are often not understood by the user. A requirement that may have been a necessity in the past is now no longer necessary because of advanced technology, but still may be specified as a requirement. For example, MIL-L-58207 requires cockpit clocks to have 15 jewels, and hands for the seconds, minutes, and hours, rather than specifying what the accuracy of the clocks should be. This means that a contractor who proposes an old style clock which would not keep accurate time would be considered responsive, whereas a contractor who proposed a highly accurate solid state digital clock would be considered unresponsive, unless the latter contractor somehow incorporated hands and 15 jewels into his digital clock.

7. The rationale for the requirement in a specification may be lacking, which makes people reticent to change the specification because they do not understand the intent of the original writer.

These examples of implementation problems highlight the need to improve the traditional system for writing specifications.

OMB Circular A-109

Impetus towards the development of an improved system for writing development specifications was provided in April 1976 with the issuance of Circular A-109 by the Office of Management and Budget (OMB). This circular requires the agencies of the Federal Government, including the DoD, to think more in terms of specifying mission requirements that need to be satisfied rather than in terms of equipment needed to satisfy a mission. The equipment needed is defined by technical specifications. The derived A-109 requirement to specify development requirements in terms of mission needs should conceptually reduce many of the specification problems noted earlier since many of the problems were caused by specifying requirements in terms of hardware needs.

Just prior to the issuance of A-109, a Deputy Secretary of Defense Clements memorandum dated 8 August 1975 entitled, "Specification/Standards Application," charged the Defense Science Board Task Force with the review of military standards and specifications. The Defense Science Board Task Force issued a report in April 1977 which recommended a program throughout DoD to improve specifications to satisfy several of the A-109 needs.[11] This recommendation echoed an earlier Office of Federal Procurement Policy recommendation to tailor specifications and standards to avoid nonessential constraints on contractors -- specification tailoring is, in part, a forerunner of Mil-Prime.[12]

A-109, in fact, also requires the tailoring of specifications and standards, i.e. the selective application of parts of specifications and standards, during certain phases of the major system acquisition cycle in which the Government interacts with contractors. The major system acquisition cycle, according to the Office of Federal Procurement Policy, consists of the following seven phases: mission analysis; evaluation and reconciliation of needs; exploration of alternative systems; competitive demonstrations; full-scale development, test and evaluation; production; and deployment and operation.[13] These seven phases are collapsed into four phases by the Department of Defense as follows: conceptual, validation, full-scale development, and production; but the concept of a multi-phased acquisition cycle does not change.[14]

During the "exploration of alternative systems" phase, which is the conceptual stage of the major weapon system acquisition cycle, the program manager's acquisition strategy must consider the tailoring of the specifications and standards;[15] and the Government solicitation requesting alternative systems must not restrict the contractors by specifying or referencing Government specifications and standards.[16] During the "competitive demonstration" phase, which is the demonstration/validation stage of the weapon system acquisition cycle:

> Contractors should not be restricted by imposing arbitrary compliance with Government specifications and standards. Such may be referenced, but alternatives which might lead to a better system should be encouraged.[17]

Mil-Prime

OMB Circular A-109, as mentioned earlier, requires a mission orientation in the weapon system acquisition process in lieu of the former hardware orientation. ASD initiated an effort in January 1976 to correct the numerous implementation problems caused by the way in which specifications for aeronautical systems have been written. This effort was ASD's own response to Deputy Secretary of Defense Clements' 8 August 1975 memorandum to review military standards and specifications. Clements' memorandum called for more attention to the development and maintenance of specifications before the issuance of requests for proposals, policies to avoid the blanket use of specifications, and most important, the necessity to force technical activities to "scrub and tailor" specifications.[18]

ASD's response to the Clements memorandum was a decision to modify its aeronautical specifications in a format that would force its engineers to tailor the requirements. This modification effort was entitled "Mil-Prime." The Mil-Prime effort focuses on providing development specifications associated with aeronautical weapon systems.

The Mil-Prime effort is divided into

three types of development documents: specifications, standards, and handbooks.[19] Mil-Prime specifications state operational needs, general parameters, and interface requirements for a physical product class. The specific values applicable to the weapon system to be acquired, e.g. the range, altitude, frequencies, etc., are filled in by the responsible Government engineer before the issuance of the request for proposal. This "fill in the blank" concept forces specification tailoring.

The Mil-Prime specification becomes the Government's Type I specification, formerly called a Part I specification. The Type I specification incorporates only performance requirements, as determined by the mission, the operational need, and interface requirements. Subsequently, the contractor will incorporate this specification into his baseline control system as his Part I specification. The Type II specification (the "build-to" design specification) will now be developed by a contractor. The end items of a contract would include the hardware, and the Type II specification for reprocurement purposes.[20]

The Mil-Prime standards provide the criteria and qualities applicable to all hardware and are not aimed at any one product. For example, Mil-Prime standards will be developed for reliability and maintainability requirements.

The companion Mil-Prime handbooks contain technical rationale for each specification and standard, provide guidance for applying the specifications and standards, and are a depository for lessons learned in each technical area. The handbooks explain where a requirement came from and why the requirement is still valid. The handbooks serve as the logical departure point for arguments about the validity of imposed requirements because the origin of the requirements for the first time, are readily available. Each handbook also identifies the Government engineer who is responsible for monitoring the handbook, which is a departure from the old concept. Allegedly, some Government engineers have resisted changes in the past by hiding behind a shield of anonymity.

The relationship among these three Mil-Prime documents -- the specification, standard, and handbook - - may be clarified by means of the following example. The Mil-Prime specification for aircraft "fuel systems," MIL-F-87154 (USAF) dated 15 August 1980, includes in paragraph number 3, entitled "Requirements," subparagraph number 3.1.1.2, as follows: "Flow performance. Fuel flow performance of each engine feed system shall be _______." The blank would be filled in by the responsible Government engineer as he tailors the Mil-Prime fuel systems specification to the specific aircraft system which he is helping to design. Paragraph number 4, entitled "Quality Assurance Provision," of the same specification has a subparagraph number 4.1.1.2, which reads as follows: "Flow performance. Fuel flow performance for each engine feed system shall be verified by _________." The blank is again filled in by the responsible Government engineer.

The Mil-Prime handbook for aircraft fuel systems includes the following information:

3.1.1.2 Flow performance. Fuel flow performance of each engine feed system shall be ___________.

Rationale - Fuel flow requirements vary with airspeed, altitude, gross weight, aircraft configuration, and other variables.

Guidance - For single engine aircraft the feed system should provide flow for 100 percent of the maximum fuel consumption of the engine in addition to any fuel flow for cooling purposes and motive flow for fuel driven pumps. For multiple engine aircraft, a feed system must provide flow for cross-feed of at least one additional engine at full power; therefore, the engine feed system should provide a minimum of 200 percent of the maximum fuel consumption of the engine plus any fuel flow required for cooling.

Lessons Learned - Potential growth fuel flow should be included in determining flow performance. Fuel flow growth for transport type aircraft is a real possibility.

<u>Verification</u>: 4.1.1.2 Fuel flow performance of each engine feed subsystem shall be verified by _________.

<u>Verification guidance/rationale</u>: The flow performance of each engine feed system should be verified by analyses and tests on a simulator and during flight tests.

Lessons Learned - Both fuel temperature and altitude as well as rate of change of altitude have a great effect on the ability of the feed system to deliver fuel. These critical parameters should be clearly stated in the test procedures. Flow performance tests should be conducted in association with fuel availability tests.

A Mil-Prime standard for reliability provides the reliability requirements for the overall aircraft system. Paragraph 3.5 of the Mil-Prime fuel systems specification provides the specific reliability requirements for the fuel system, and paragraph 4.5 of the same specification provides the mean by which the specific reliability requirements may be verified.

The Mil-Prime specifications and standards are part of the specification tree in weapon systems acquisitions. Specification requirements are levied to satisfy the Air Force's objectives of lower unit costs, better reliability and maintainability, and standardization. One significant difference between the traditional system and

Mil-Prime is that with Mil-Prime the contractor or contractors have great design latitude that they did not have before because of the specific mandatory requirements imposed by the traditional aeronautical specifications. Another significant difference is in the area of standards for the flying qualities and "ilities," e.g. reliability, maintainability, quality, etc. The traditional standards, unlike the Mil-Prime standards, do not incorporate a separate "lessons learned" section. Engineers using the Mil-Prime standards are provided with a handbook containing "lessons learned," including the reasons why certain requirements and verification techniques are called for in section 3 and 4.

The result of the Mil-Prime effort should be that the numerous technical requirements of Air Force aeronautical research and development contracts which drive cost growth will be brought further under control, which in turn should help bring the cost growth of major weapon systems under control. In the process, Mil-Prime lays the ground work for a specification system that is more responsive to the needs of the using commands; that provides more flexibility for innovation; that establishes a repository for lessons learned; that provides contractor feedback to Government engineers; that reduces over specifying, tiering, and paperwork; and that accomplishes the DoD objectives as stated by the 8 August 1975 Clements memorandum.

Currently there are approximately 60 aeronautical specifications which ASD has decided to rewrite in the Mil-Prime format. The Mil-Prime effort is targeted for completion in 1982. As of 29 April 1981, ASD had spent 24,000 manhours developing the Mil-Prime documents, but had succeeded in completing only five of the 60 documents; however, twelve additional documents were in completed draft and over 40 others were underway.[21]

The first request for proposal (RFP) using any Mil-Prime document was issued in October 1980. This RFP, for the C-X aircraft, incorporates a specification that was written by some of the engineers who were currently drafting the 60 Mil-Prime documents, with the result that the specifications for certain subsystems of the C-X aircraft have been written using the Mil-Prime format as a guide.

Analysis and Findings

The Interviewees

Eight ASD engineers who have had some experience with Mil-Prime were interviewed. Some of the engineers actually wrote Mil-Prime specifications and handbooks; others used or supervised the use of these Mil-Prime documents to develop specifications for specific weapon systems, e.g. the C-X, LRCA (Long Range Combat Aircraft), and the engine for the NGT (Next Generation Trainer). Those engineers who were responsible for developing specifications for specific weapon systems used the Mil-Prime documents as a guide, rather than as a format that had to be rigorously followed. Mil-Prime is viewed by these engineers not as a rigid format that had to be followed, but as a concept that requires the specification of performance requirements in one document as opposed to the practice of referring the potential contractors to multiple military specifications. These engineers view Mil-Prime as a new means of communicating to a contractor the performance required for a piece of equipment; the specific design of that equipment, i.e. the Type II specification, is still the responsibility of the contractor.

Specification Development

The Mil-Prime landing gear specification was the first Mil-Prime specification completed, and it was distributed to all other Mil-Prime authors as an example to be followed. The Mil-Prime landing gear specification is considered by the engineers interviewed to be representative of other single-system Mil-Prime specifications. Single-system specifications, e.g. the landing gear, parachute systems, and fuel systems specifications, are conceptually different from the more general systems standards, e.g. the system reliability standard. However, the multiple discipline standards, according to one of the authors are expected to follow the same Mil-Prime format used in the Mil-Prime landing gear specification.[22]

The Mil-Prime specifications were developed by reviewing all the relevant traditional specifications; deciding what parts of those specifications should be preserved; combining similar subsystems together, e.g. wheels, brakes, and tires; and then "cutting and pasting" until the Mil-Prime specifications emerged.[23] Essentially, all the traditional specifications and standards were looked at with the intent of replacing them by (1) updating all the traditional requirements; (2) expressing the traditional requirements in terms of operational needs; and (3) ensuring that there were means of verification to correspond with the specified requirements.[24]

The C-X, which is the first weapon system to apply the Mil-Prime concept, incorporates a landing gear specification that was developed, according to the specification's author, using the Mil-Prime landing gear specification as a guide. Because many members of the C-X development group also participated in the since cancelled AMST (Advanced Medium Short Takeoff and Landing Transport) program, the AMST landing gear specification was also used to develop the C-X landing gear specification. The AMST specification was developed using a Mil-Prime philosophy before the details of Mil-Prime were formulated. The AMST engineers were told to write a specification that minimized the use of reference

specifications and that maximized the emphasis on performance.[25] The engineers in the C-X program not only used the AMST specification as a baseline, but were also directed to use Mil-Prime documents for those areas of the aircraft where the Mil-Prime documents were not available, i.e. if Mil-Prime documents were not yet developed for an area of the aircraft, the C-X engineers were directed to use the Mil-Prime approach.[26] Thus, the C-X landing gear specification does not completely follow the Mil-Prime format because the AMST landing gear specification, which had already undergone rigorous review by both the internal ASD engineering committees and by defense contractors, was available and generally applicable for use by the C-X program.[27] All Mil-Prime specifications have flexibility to make some changes in format and content outside of the handbook writing guide but still must be faithful enough to the concept to pass an ASD review committee.[28] The C-X fits this range.

The use of a Mil-Prime specification in conjunction with another aircraft specification, e.g. the AMST specification, is by no means unique. The landing gear specification for the LRCA was developed using the Mil-Prime, C-X, B-1, and FB-111 landing gear specifications, along with the LRCA statement of work, and information from the "problems" file of past landing gear problems. Some of these "problems," incidentally, had already been documented in the original version of the Mil-Prime landing gear handbook.[29]

A summary of the specification writing process using Mil-Prime is depicted in Fig. 1.

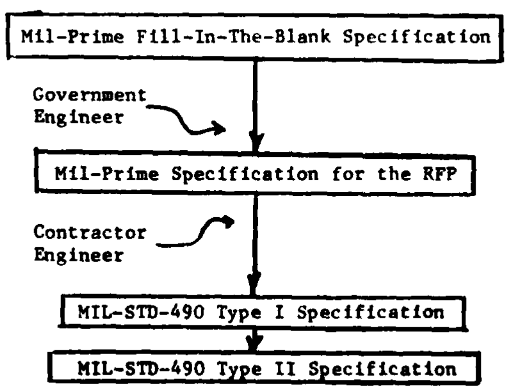

Fig 1. The Specification-Writing Process Using Mil-Prime

A Government engineer would use a Mil-Prime "fill-in-the-blank" specification to develop a Mil-Prime specification for a specific system or subsystem of an aircraft. This latter specification would be incorporated into the request for proposal (RFP). Potential contractors may respond to the RFP with their own Type I specification in the MIL-STD-490 format, or they may accept the Government's specification that was incorporated into the RFP as the final Type I specification. The contractor who wins the contract award would then develop the Type II specification in the MIL-STD-490 format.[30]

The engineers interviewed more readily identified differences between the traditional and Mil-Prime systems than they identified similarities. Yet the similarities that they identified are significant. The total approach to specification requirements is similar. Mil-Prime is essentially a rewrite of traditional specifications using the same six section format, and in many cases using the exact wording from the traditional specifications. The same performance requirements exist with both systems, except Mil-Prime expresses these requirements more explicitly. The baseline verification section (section 4) is essentially the same for the two systems but Mil-Prime more rigorously ensures that verification of each requirement is specified. For example, the MIL-B-8584 problem, cited earlier, in which an aircraft parking brake was required to hold an aircraft on an 18^{c} slope (with no means of verifying this requirement specified) would not be a problem under Mil-Prime because Mil-Prime's format ensures that verification of each requirement is specified in terms of performance.

A comparative analysis of section 3 (requirements) and section 4 (verification) in the C-X (Mil-Prime) and C-5 (traditional) landing gear specification is summarized in Fig. 2. This comparative analysis reveals that there is a direct/absolute correlation between all subparagraphs in section 3 of the C-X specification with all subparagraphs in section 4 of the same specification. But the correlation for the C-5 was significantly different from the C-X. Of the 16 major subparagraphs for the C-5, numbered 3.3.1.7 to 3.3.1.7.9 in specification No. CP40002-2B, ten subparagraphs had absolute/direct correlation; and one subparagraph, number 3.3.1.7.5, had a generally applicable relationship with corresponding paragraphs in section 4. More significantly, five of the subparagraphs did not have any corresponding paragraphs in section 4. This indicates a strong potential that there was not any contractually specified means of verifying, for example, the testing of the landing gear warning horn (paragraph 3.3.1.7.1.3), or the operation of the emergency brake (paragraph 3.3.1.7.4). The verification requirements in the Mil-Prime landing gear specification incorporate a numbering system which corresponds to that used in section 3 so that the verification requirement relates more directly to its performance requirement.

Number of Requirements with a:	C-X	C-5
direct/absolute correlation	79	10
generally applicable correlation	0	1
vague/no correlation	0	5
Total	79	16

Fig 2. Correlation Between Section 3 and Section 4

Other differences (identified by the engineers) between the traditional and Mil-Prime systems were found. The traditional specifications often incorporate lessons learned in the specifications themselves by specifying more detailed requirements that solved the previous problems. The Mil-Prime specifications are exclusively performance oriented, with references, procedures, and lessons learned delegated to the accompanying Mil-Prime handbook.

Several engineers stated that the concept of tailoring specifications highlights a significant difference between Mil-Prime and the traditional specifications. "Tailoring," in its classic definition, is taking a product (e.g. a suit) and cutting away material until it fits a customer. Mil-Prime is a philosophy where the minimum necessary material is measured, cut and sewn together. The traditional specification could be tailored by deleting aspects of the specifications that were judged not to be applicable to a specific weapon system; the Mil-Prime specifications are designed from the outset for a specific weapon system. In the past, the contractors would, in general, anticipate what the Government's specification in the RFP was going to say since the same specifications were referenced over and over again. With Mil-Prime, the contractors apparently will have to spend significantly more time with the Government engineers before issuance of the request for proposal to have as complete an understanding of the Air Force requirement; otherwise, the contractor will have little idea how the Government engineer is going to fill in the blanks, i.e. tailor the Mil-Prime specification to a specific weapon system. The Mil-Prime system may lead contractors to question many filled-in blanks to see if the Government is serious about those requirements, whereas in the past contractors were hesitant to question specifications which had been used over and over again. This expected questioning of the tailoring process by contractors, if allowed to happen, should potentially result in a reduction in the number of requirements which would allow the contractors flexibility to design a weapon system that meets the essential requirements at a lower cost.

The expected questioning of the tailoring process by contractors should, according to several of the engineers interviewed, also encourage Government engineers to do their homework well before issuing the specification to industry. In the past, Government engineers depended on the traditional specification to cover the requirements waterfront and to cover up for an engineer's lack of specific knowledge concerning certain areas of a specification. This often led to referencing every general specification dealing with the system or subsystem for which the engineer was responsible. With Mil-Prime, the Government engineer must address each discipline when he specifies the requirements; no longer can he depend on referencing specifications and postponing learning the details of those specifications until he reads the contractors' proposals. Mil-Prime thus requires more front-end effort by Government engineers; Mil-Prime essentially provides a checklist guide for the Government engineer's front-end efforts.

The rewriting of the specifications into the Mil-Prime format will force the constant review of outdated and undesirable requirements and specifications. For example, a rewriting of MIL-L-38207, cited earlier as requiring 15 jewels in the clock on an aircraft instrument panel, would specify performance characteristics rather than design characteristics for a clock, which would, in turn, allow the use of the more modern digital clocks. By cleansing the system specifications of many unnecessary design details and design requirements, both the contractor and Government purchasing groups eliminate unnecessary manhours, paperwork, and cost to justify non-compliance to specifications which are not applicable.

Another factor favoring the Mil-Prime system, according to several of the engineers, is its exclusive performance orientation. Unlike the traditional specifications, the Mil-Prime specifications get away from driving a contractor to a specific design. A contractor will have greater latitude to meet these performance requirements by balancing cost, weight, and performance characteristics in an optimal fashion than he would if constrained by a design limitation. Significantly, the statement of the requirements in terms of operational needs in the Mil-Prime specification should eliminate some of the cost drivers in the traditional specifications by allowing the contractors more flexibility of design. The contractor's innovations will be less stifled by a fear of going against a military specification and being accused of being nonresponsive.

The exclusive performance orientation which Mil-Prime emphasizes could bring about problems in verification, according to one engineer. For example, in the case of a radio which is required to transmit for 100 miles, many variables will influence the performance of the radio, such as atmospheric conditions, terrain, and personnel testing the equipment. In a

traditional specification, a design requirement would usually be specified which required that radio to broadcast with an output of 30 watts, for example, which is very simple for an engineer to verify. Verification of the 100-mile transmission requirement under variable conditions will be more difficult to accomplish.[31]

Another aspect causing concern among some of the engineers is that more discussion is required between the ASD engineers and the operating or using command of what is really needed prior to the issurance of the request for proposal. Most using commands are not tuned to supplying engineers with functional design. For example, project personnel of the using command talk of combat turn radius, while engineers speak of degrees of bank at a given airspeed.

The Mil-Prime emphasis on performance improves communication between the engineer and the using command. When the engineer used the traditional specification he wrote in a language that the user did not understand, e.g. he specified what the pounds of thrust of the engine would be under various flight profiles, but did not dwell on what the impact of the level of thrust would be on operational requirements. When the engineer uses Mil-Prime, discussion with the using command is enhanced because the engineer is writing more closely to the operational language that the user understands, and the user is better able to communicate his needs with the engineer.

The traditional specification approach often called for each subsystem to be designed and laboratory tested as an entity within itself prior to being mated with the other subsystems to comprise the entire system. However, in some cases, the sum of the whole does not equal the sum of its parts. For example, the F-15's tires wore unacceptably on their edges after approximately nine landings because of poor integration with the landing gear. The traditional specifications called for tires and landing gear separately. Both subsystems met the laboratory verification requirements, but were not required to be mated and tested. The prime contractor was often not held responsible to ensure that the landing gear and tires worked well together if no violation of each independent specification could be pointed out. This was often viewed as the price of uncertainty and borne by the government. Even the evolved concept of "Total System Performance Responsibility" (TSPR) so often claimed as a hold by the government over prime contractors gets deluted and negotiated away in the face of ambiguous and conflicting sub-specifications. Neither the tire nor landing gear contractors could be held responsible for the unacceptable wear of the tires since both contractors successfully completed their respective laboratory tests and design requirements.

A Mil-Prime specification will call for a landing gear capable of allowing, for example, at least 50 landings per tire. If the aircraft did not satisfy this specific performance requirement, then, under TSPR, the prime contractor would clearly be responsible for correcting the landing gear's design problem.[32] This means of designing weapon systems generally transfers all down the line the focus on acceptance of the weapon system to the total weapon system performance rather than the laboratory performance of the individual subsystems.

Mil-Prime's handbook provides the corporate memory, through its lessons learned, which should prevent problems like that with the F-15 landing gear from occurring. The handbook must, however, continuously be updated to maintain its currency so that no innovative designs are overlooked. An example would be the carbon brakes used on landing gears. The first couple of generations of the carbon brakes were plagued with problems and were inferior to the standard steel brakes. Succeeding generations of the carbon brake overcame the problems encountered, and are now as good if not better than the steel brakes. If the handbook were not kept current with the advances made with the carbon brakes, engineers who were not intimately familiar with the material would rate the design specification of a contractor who proposes the use of carbon brakes as inferior.[33]

A new system, such as Mil-Prime, could not be expected to be implemented without causing some problems. The Government loses some control over the contractors because the contractors now have more design discretion. The emerging details of each aircraft subsystem, which were previously controlled by the Government engineer, are now a contractor's responsibility. All the contractor must show early in his development is a plausable correlation to performance oriented requirements - remember that the verification section is also performance oriented and thus less susceptible to a piece-meal, test-as-you-go check on evolving design. It is possible that problems could develop as a result of not following the dictates of the traditional specifications. On the other hand, according to some of the engineers interviewed, the transfer of emphasis from accepting subsystems in a laboratory environment to acceptance of a total aircraft basis should cause a lessening of costly engineering change proposals that were necessary because problems did not surface in the laboratory, but did surface during aircraft performance.

Mil-Prime, according to the engineers interviewed, could also make the working environment more intense for the Government engineer because he will have to pay more attention to the specification before it is released to the contractors. On the other hand, paying more attention at the front-end should result in a better product down the road. Of course, if engineering manpower is constrained and not enough time is

available to spend at the front-end, problems could develop as a result. Then again, if the Government must depend on new, inexperienced engineers, engineers who could not reasonably be expected to develop adequate specifications using the multitude of traditional specifications, Mil-Prime will enable these engineers to develop adequate specifications by following the Mil-Prime fill-in-the-blank specification checklist. New or inexperienced engineers may run the risk, when using the Mil-Prime specification, of omitting necessary requirements which, some engineers fear, could require expensive change proposals if the omissions are not found prior to full-scale development. This was not a problem when the traditional specifications were used, since an engineer, when in doubt about a requirement or a group of requirements, could always reference the appropriate military specifications and be assured that he had covered the requirement.

Mil-Prime's claimed ease of implementation, i.e. its simplicity and its flexibility, versus that of the traditional specification system is an important issue. Most of the engineers interviewed believe that Mil-Prime will be a simpler system from the Government manager's point of view, but more difficult from the lower level project engineer's point of view. This being true because the Government's level of control is higher, i.e. at the aircraft performance level rather than at the subsystem level, so that there should be a greater ease of implementation of the essential requirements. For example, monitoring qualification testing at the aircraft level will be less of a burden for the Government than monitoring qualification testing at all vendor levels. Furthermore, keeping the Mil-Prime handbooks up to date, which may be a challenging task because of manpower constraints, would be an easier task, according to some of the engineers interviewed, for the ASD engineering community as a whole because it is easier to update approximately 60 Mil-Prime specification handbooks than several thousand traditional specifications.

From the Government engineer's point of view, it was claimed that there will be the need to pay more attention to the initial requirements that are sent to the contractors. The traditional specifications could be readily implemented in one paragraph of referenced specifications, while with Mil-Prime a Government engineer must be aware of every requirement he is specifying. No longer will the Government engineer be able to rely on the multitude of military specifications to cover for his lack of knowledge or preparation.

The contractor's engineers, again according to some of the Government engineers interviewed, will find that the unrestricted freedom of design makes their design decisions much more difficult because of the number of options available to them. When the traditional specifications were used, a design requirement was usually specified which constrained the contractor's descretion on how the subsystem was to be designed - this phenomenon leading to small, incremental changes on existing design which had already passed government acceptance testing. Thus the testing (or evaluation) tended to focus on the <u>changes</u> rather than the performance of the newly evolved system. This "change" philosophy also worked for the new (vs old) environment. If a black box had been only slightly modified from one meeting $-40^{o}F$ operating conditions, there was considerable pressure to test a new box with $-65^{o}F$ operating requirements only in the -40^{o} to -65^{o} range. With Mil-Prime, the contractor's engineers will have to design their own subsystems and verification requirements are more squarely on their shoulders.

Mil-Prime's flexibility appears to be less questionable with the engineers interviewed than its simplicity. Mil-Prime presents the opportunity for the contractors to enter into discussions with Government engineers as to what approach is best for a specific aircraft. In the past, these discussions were discouraged because the Government engineer depended on the "locked-in-concrete" traditional specifications to establish the requirements.

<u>Acceptance of Mil-Prime</u>

Because Mil-Prime represents a change to the traditional way of doing business at ASD, one would expect both acceptance of and resistance to the change. Defense contractors have been giving positive feedback, the engineers say, regarding Mil-Prime. The Aeronautical Industries Association, the Electronics Industries Association, and the Society of Automotive Engineers have reviewed specific aspects of Mil-Prime and have indicated that Mil-Prime is a change for the better.[34] Some criticism of Mil-Prime to date (from industry) has been related to the detailed descriptions of the lessons learned in the Mil-Prime handbooks; apparently some contractors are sensitive that their past mistakes are being published in a Government document.[35] Other criticism from industry seems to relate possibly to a "not invented here" attitude; this causes resistance that might dissipate if contractors believe that the new flexibility that Mil-Prime gives them is not outweighted by new, more forceful performance commitments. There is also a feeling, according to some of the Government engineers interviewed, that Mil-Prime will not be well received by the working level engineers in contractor organizations. Mil-Prime may make these engineers uneasy because they are used to having the Air Force tell them what to do and then applying what the Air Force says to their design; Mil-Prime requires these engineers to do more thinking, to exert more control, and to be more original, all of which is a change from the traditional practices.

The ASD engineering community, as represented by the engineers interviewed, also has been giving positive feedback regarding Mil-Prime. Initial impressions were characterized by skepticism, apprehension, and reluctance, partly because many Government engineers were used to detail control over technical specifications, which they did not want to relinquish and partly because some Government engineers relied upon the traditional specifications as a "security blanket" that they could fall back upon. But the attitude of many ASD engineers seems to have changed as they listened to advocates of Mil-Prime within the ASD engineering community, as they help develop these Mil-Prime products.

Conclusion

Objective indicators generally support the ASD engineers contention that Mil-Prime results in simpler, more flexible specifications. As noted earlier, this may not correlate with ease of writing as one might expect. In fact, early government and contractor negotiation will likely be more intense, and hopefully meaningful. The principle pay-off of Mil-Prime is likely to be in clearer contractual understanding and especially verification, of what the contractor delivers in accordance with what the government requires.

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